THERMAL BURDEN OF PROTECTIVE FACEMASKS

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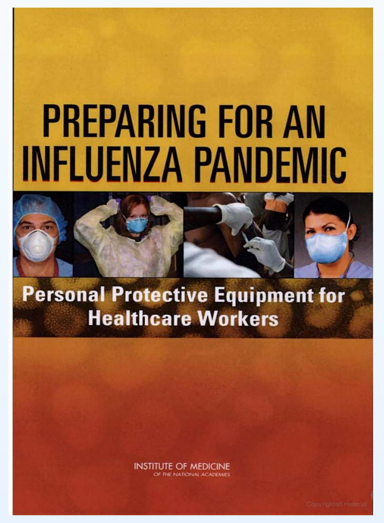
Objective

To evaluate the thermal burden of specific models of protective face masks (PFM), namely filtering facepiece respirators (FFR) and surgical masks (SM), using wireless technology (Figure 1)

Background

- Failure to properly use respirators has been identified as a possible cause of patient-to-healthcare worker transmission of infection. Compliance with recommended use of respiratory protection has been found to be below 60% in various clinical settings.
- The Institute of Medicine (IOM) recommended increased research on the design and engineering of the next generation of respirators for HCWs that would enhance their safety, tolerability and comfort.



- PFM are worn by approximately three million industrial and manufacturing employees in the U.S. and millions of others in the healthcare industry, as well as significant numbers of the public during respiratory infectious disease outbreaks (e.g., pandemic influenza, SARS, etc.).
- One of the most commonly reported complaints of discomfort voiced by wearers of most types of PFM is the perception of increased facial and body heat which can lead to PFM intolerance and associated non-compliance.
- The body normally maintains its temperature within narrow bounds by eliminating excess heat from various sources (e.g., basal metabolism, environmental heat, etc.), but the use of PFM can impair heat elimination mechanisms such as respiratory heat loss (8% - 15% of total body heat loss) and facial skin convective and radiative losses (approximately 2% of body surface area).
- Previous studies addressing the impact of PFM upon body temperature parameters have suffered from 1) the use of thermal data captured from anatomic sites that do not accurately reflect core temperature, (e.g. , oral and tympanic temperatures) and 2) the need for hard-wired instrumentation (e.g., thermisters, sample ports, etc.) of the PFM that could alter its fit and function.

Figure 1. Wireless temperature monitor, dermal patch and core temperature pill (A). A humidity and temperature sensor attached to the inside of a respirator (B).

Methods

- Ten healthy subjects (8 men, 2 women), 80% of whom had no prior PFM experience, were recruited and tested over a two month period.
- Subject descriptive statistics: age 23 ± 2.9 years, height 178.6 ±11.3 cm, body weight 79.9 ±17.2 kg, and Body Mass Index 24.9 ±4.1 kg/m^2.
- All subjects first underwent quantitative fit testing with cup-shaped and flat fold respirators that are manufactured with and without exhalation valves and a flat, pleated SM (though the SM was not expected to pass) (Figure 2). In order to participate in the treadmill tests the subjects had to pass a fit test for all 4 FFR.
- Subjects treadmill exercised continuously for one hour at a low-moderate work rate (3.5 mph [5.6 km/h]; 0° inclination) with no PFM (baseline) and wearing randomly-assigned PFM.
- Core body temperature was continuously monitored via an ingested wireless core temperature capsule, and body surface temperatures were measured with wireless dermal sensors at various cutaneous sites: right buccal region, left upper abdominal quadrant area, and left facial area covered by the PFM (Figure 3).
- Comparisons of mean baseline and PFM-associated temperatures over the course of one hour were analyzed using paired t-tests, with a p<0.05 considered statistically significant (Table I).

A

Figure 2. PFM worn by subjects during this study.

Figure 3. Dermal patch location with and without a donned PFM.

Results

- No significant difference was noted between baseline (no PFM) and PFM – associated core temperatures, right buccal region skin temperatures, and abdominal skin temperatures over one hour of treadmill exercising at 3.5 mph (5.6 km/h).
- There was no significant difference in core temperatures or cutaneous temperatures (covered or not covered by PFM) attained while wearing FFR with or without an exhalation valve.
- There was a significant difference in the facial skin temperature covered by a PFM compared to facial skin on the opposite side of the face that was uncovered (p=<.01 for each model).
- The mean PFM-deadspace temperature/relative humidity were 33.03 °C (range 30.78 – 35.02 °C) and 80.21% (range 56.59 – 97.41%), respectively.
- There is no significant difference between surgical masks and FFR (with or without exhalation valves) on the thermal burden afforded.

Table I. Comparison of baseline (no PFM) and protective facemask – associated core and cutaneous mean temperatures over one hour at 3.5 mph [5.6 km/h].

Protective Facemasks (PFM)	Temperature (C^O) Core	Facial Skin	Covered Facial Skin	Abdominal Skin	PFM Deadspace
Baseline	37.46 (±0.24)	32.48 (±0.90)	32.48 (±0.90)	32.78 (±0.75)	N/A
3M 9210	37.62 (±0.25)	32.30 (±1.00)	33.64 (±1.04)	33.18 (±0.87)	33.55 (±0.44)
3M 9211*	37.48 (±0.26)	32.19 (±0.87)	33.51 (±0.72)	33.51 (±0.68)	32.51 (±1.20)
Moldex 2200	37.56 (±0.32)	32.40 (±0.97)	33.77 (±0.74)	33.22 (±0.97)	33.50 (±0.86)
Moldex 2300*	37.53 (±0.29)	32.37 (±1.14)	33.33 (±0.67)	32.90 (±1.01)	32.56 (±1.40)
Kimberly-Clark Surgical Mask	37.60 (±0.29)	32.40 (±0.72)	33.69 (±0.64)	33.18 (±0.31)	33.18 (±0.70)

*** PFM with exhalation valves.**

Conclusions

- PFM tested in the current study at a low-moderate work rate continuously for one hour in a temperate ambient environment did not add appreciably to the body heat burden.
- At a low-to-moderate work rate, exhalation valves on FFR tested in this study offered no significant benefit in facial heat buildup or core temperature when compared to FFR without exhalation valves.
- The thermal burden imposed by the surgical mask model tested in the current study is not significantly different from that of the tested FFR (with or without exhalation valves).

Future Directions

- Finish collecting data on the remaining 10 subjects.
- Employ more sophisticated statistical methods to analyze the data.
- Investigate potential associations between thermal measurements and other comfort and tolerability variables: facial pressure, air permeability of the respirators, and subjective responses regarding exertion and heat while walking on the treadmill.